Color discrimination and luminance

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This experiment studied the relation between luminance level and color discrimination at 570 millimicrons. A variety of stimuli whose luminances varied from .1 to 100 ft-L were viewed against a variety of surrounds. It was found that color discrimination ability was a joint function of the luminance level of the stimulus and the ratio of the luminance of the stimulus to that of the surround.

Although the relation between wavelength and hue discrimination has received much attention recently (Siegel & Dimmick, 1962; Siegel, 1964), surprisingly little has been written about the relation between luminance and hue discrimination. The classical study of Purdy (1931) as well as more recent experiments (Boynton & Gordon, 1965; Beare & Siegel, 1967) have demonstrated that hue is indeed influenced by luminance. Only one study sought specifically to determine the effect of luminance on hue discrimination (Connors, 1964). In her experiment, Connors studied hue discrimination at 550 millimicrons for three different stimulus luminances, .06, .2, and 2.0 ft-L, with a variety of surround luminances. She reported that although the appearance of the stimulus was greatly altered by changes in the ratio of the stimulus to the surround, surround luminance alone did not influence the threshold over a range of three log units.

The present study is an attempt to verify and extend these findings for a different wavelength and at a different range of stimulus and surround luminances.

APPARATUS

The apparatus used was a Farrand monochromator with a 1000-mm focal length identical in design to the one described by Connors (Connors, 1964, p. 693). This instrument provided a horizontally divided field that subtended 2 deg at the O's eye. A 1000-W xenon arc served as the light source and permitted luminance values as high as 100 ft-L with a 10 millimicron bandwidth at the 570 millimicron standard. The stimulus appeared through a circular hole in a surround screen that was illuminated from above and behind the O. The surround illumination was maintained at a color temperature of Illuminant C although the luminance could be changed. A sector shutter provided discrete .2-sec exposure of the stimulus field. Calibrations of wavelength, luminance, and exposure duration were made both before and after the experiment. No changes in the preexperimental values were detected.

PROCEDURE

The method of constant stimulus differences was used. There were four different stimulus luminance levels: .1, 1.0, 10.0, and 100 ft-L. The same four luminance levels were used for the surround. Each experimental session consisted of two series of judgments. In one, Os were asked whether the lower or variable half of the field was "yellower or not yellower" than the upper or standard half of the field for each of 50 stimulus pairs. In the other series, Os were again presented with 50 stimulus pairs, but were now asked to judge whether the lower half of the field was "greener or not greener" than the upper half. The order of these series was reversed for half the sessions. Two different experimental sessions were run at each of the 16 different conditions. The order of appearance of each condition is presented in Table 1.

Table 1
Order of Appearance of Conditions

		Stimulus Luminance in Foot-Lamberts			
		.1	1	10	100
Surround Luminance in Foot-Lamberts	.1	1/32	2/31	3/30	4/29
	1.0	8/25	7/26	6/27	5/28
	10.0	9/24	10/23	11/22	12/21
	100.0	16/17	15/18	14/19	13/20

The numbers in the body of the table represent the order of conditions. For example, the 1 ft-L stimulus–.1 ft-L surround condition appeared second and thirty first.

The three Os used were all familiar with the kinds of judgments required. All were emmotropic or wore corrective lenses and were free from color vision defects. All observation was made with the right eye. The left eye was occluded. A head and chin rest was used to minimize head movements.

RESULTS AND DISCUSSION

The standard deviation of the O's judgments was calculated for each experimental session and used as the measure of sensitivity. Figures 1, 2, and 3 present the results for the three Os.

Value of the standard deviation in millimicrons is plotted on the ordinate. The abscissa shows the ratio of the stimulus to the surround luminance. The four different stimulus luminance levels are plotted separately. For the .1 ft-L stimulus no observations were possible when the surround reached 100 ft-L. The entire stimulus field looked black and because of this there are no data points at the 10^{-3} stimulus/surround luminance ratio. Although there are some differences among the three Os, the curves are sufficiently similar to allow data to be combined. Figure 4 plots the mean of the data shown in Figs. 1-3. Once again, the four different stimulus luminance levels are plotted separately.

It can be seen that both for the 100 and the 10 ft-L stimuli, discrimination level remains essentially unchanged at the four surround luminances used. If anything, discrimination was slightly poorer for both the 10 and 100 ft-L stimuli at very high and at very low surround luminance values than at intermediate surround luminance levels. For the .1 and the 1 ft-L stimuli, however, the results differ. For both, as the surround luminance was increased, discrimination deteriorated rapidly. With the stimulus at .1 ft-L and the surround at 10 ft-L, the field appeared "dark and muddy" according to the Os. When surround illumination was further increased to 100 ft-L, the .1 ft-L stimulus was not visible. When the luminance of the surround was 100 times that of the stimulus, at 10^{-2} on the abscissa, the .1 and 1 ft-L stimuli looked much the same and discrimination levels were fairly close.

Figure 5 presents a summary of all data. It was obtained simply by calculating the mean value at each luminance ratio point from the data of Fig. 4. The points on Fig. 5 are therefore based upon differing numbers of measurements: only one at 10^3, two at 10^2 and 10^{-2}, three at 10^1 and 10^{-1}, and four at 10^0. Presentation of data in this form makes it clear that discrimination is unaffected by the luminance ratio from 10^3 to 10^0; however, performance deteriorates rapidly at smaller ratios.

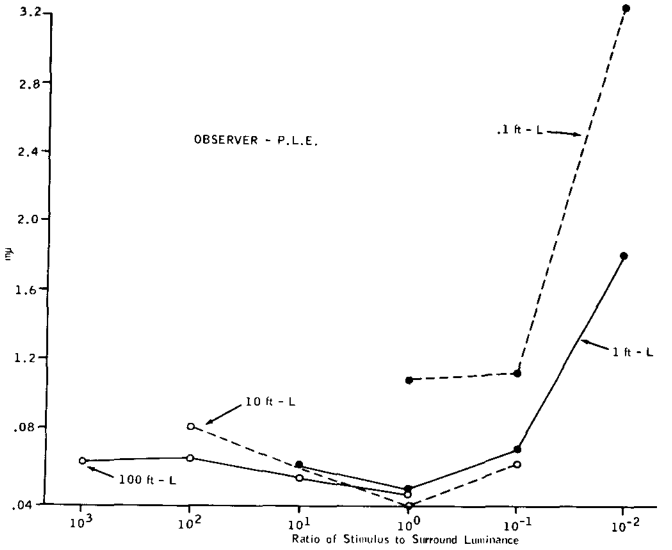

Fig. 1. Color discrimination in millimicrons as a function of the luminance ratio of the stimulus to the surround for O PLE.

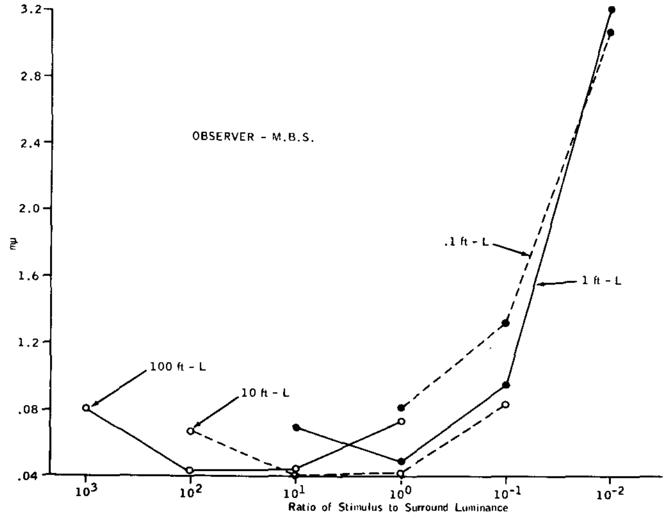

Fig. 2. Color discrimination in millimicrons as a function of the luminance ratio of the stimulus to the surround for O MBS.

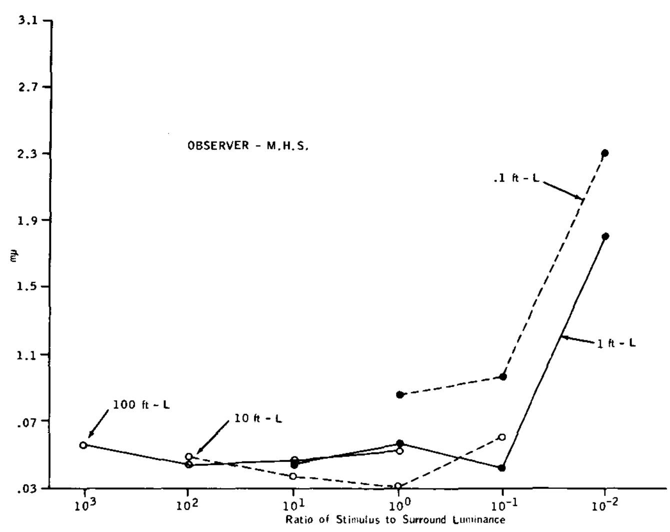

Fig. 3. Color discrimination in millimicrons as a function of the luminance ratio of the stimulus to the surround for O MHS.

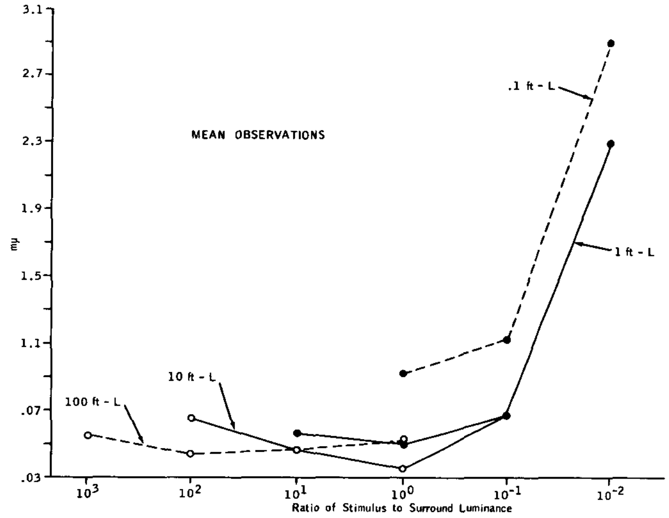

Fig. 4. Mean of the data plotted in Figs. 1, 2, and 3, plotted separately by stimulus luminances.

What, then, may we say about the relationship between color discrimination and luminance? The simplest description would reduce all data to one series of points that could be joined. Figure 5 does indeed offer such a simple description. By reducing data simply to a mean luminance ratio, one grants the significance of the luminance ratio as a determiner of color discrimination ability. The relatively smooth curve found in Fig. 5, together with our intuitive judgment that brightness, hence discrimination, is a function of this ratio, strengthens this view. A glance at Fig. 4 further confirms this position; the data points at the individual ratio values are similar. A closer look at Fig. 4 suggests that describing color discrimination ability simply as a function of the luminance ratio of the stimulus to the surround is not enough. All of the points at a given ratio value are not coincident. In addition, there appears to be an orderly progression of data points, in which, in general, low luminance stimuli lead to poorer performance than the high luminance ratio value. This suggests that performance in a color discrimination task, and inferentially, perception of brightness is, in part, a function of the ratio of the stimulus luminance to the surround luminance and, in part, a function of the value of the luminance of the stimulus alone.

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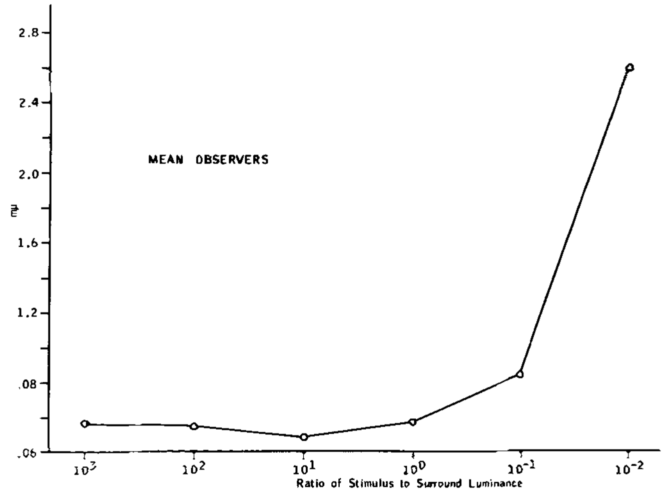

Fig. 5. Mean of the points plotted on Fig. 4. See text for full explanation.

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NOTE

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